EISCAT data analysis

From EISCAT data to ionospheric parameters

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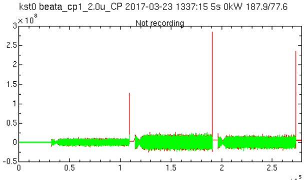
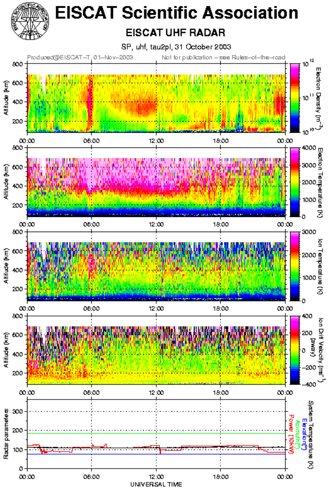
August 2019

Outline

Several of these

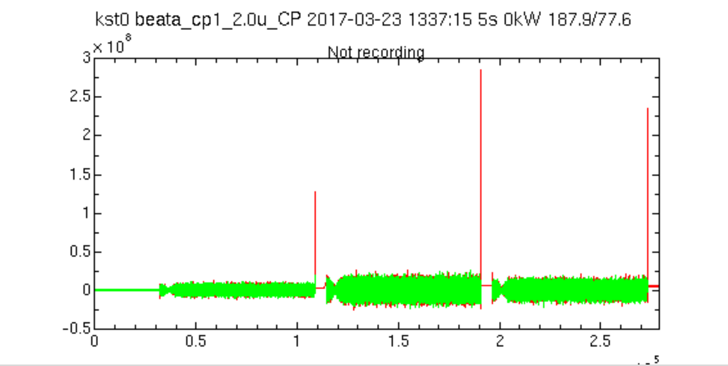


To one of these



EISCAT data files

A **d_data** dump



Principle:

- All possible 1st lags
- All possible 2nd lags
- ...

EISCAT data files

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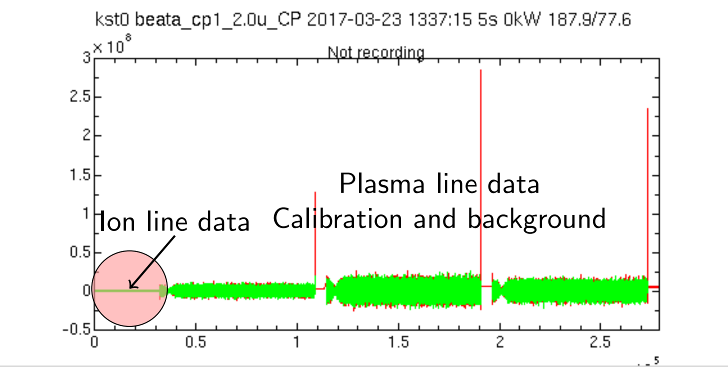


EISCAT data files

EISCAT data storage

- Directory name structure: pulse code, antenna scan, version, affiliate code, @antenna
- Hourly subdirectories
- Compressed Matlab **.mat** compatible files
- Name is seconds since New Year

EISCAT data files

Contents of data files 1

d_data Lag profiles
autocorrelation domain (Level 2) data, complex vectors, sorted:

1. lag
2. range

d_raw
- transmitter samples
- received raw voltage domain (Level 1) data

(available only from certain experiments)

EISCAT data files

Contents of data files 2

d_parbl Metadata

- Time
- Transmitter power
- Antenna azimuth and elevation
- and much more

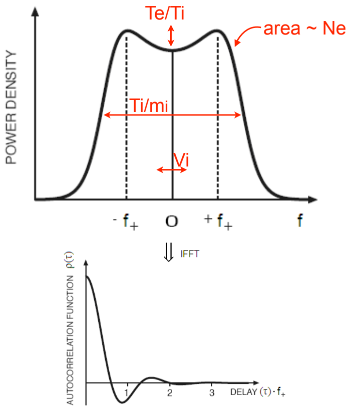
More information about data and metadata

https://www.eiscat.se/wp-content/uploads/2016/11/EISCAT-metadata_20150423.pdf

GUISDAP analysis package

- Originally "Grand Unified Incoherent Scatter Design and Analysis Package", M. Lehtinen et al.
- Maintained by I. Häggström, EISCAT HQ
- Matlab software
- Direct theory of scattering spectrum
  - Electron density
  - Ion temperature
  - Temperature ratio
  - Line of sight velocity
  - etc
- Atmospheric models (IRI, MSIS)
  - Neutral temperature
  - Density / collision frequency
  - Ion composition
- Fitting to lag profiles (following slides)

Standard parameters found by fitting the Ion-acoustic line



Ion temperature (Ti) to ion mass (mi) ratio from the width of the spectra

Electron to ion temperature ratio (Te/Ti) from “peak_to_valley” ratio

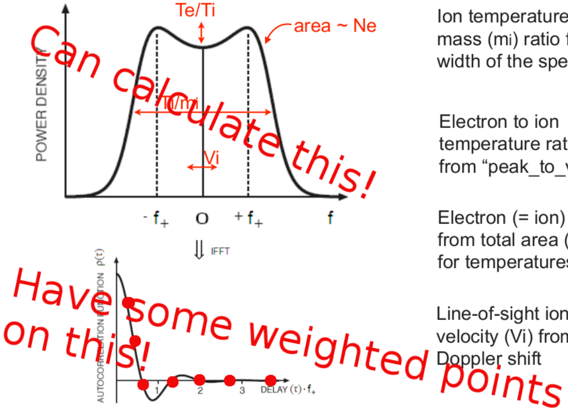
Electron (= ion) density from total area (corrected for temperatures)

Line-of-sight ion velocity (Vi) from the Doppler shift

52

Data and incoherent scatter theory

Standard parameters found by fitting the Ion-acoustic line



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Principle of GUISDAP analysis

- Applying Fourier transform theory, the theoretical spectra can be fitted directly to the lag profiles using

precalculated spectral ambiguity functions (Nygrén 1996, p. 78)

$$LP(t,t') = R \int_r P_z^0(\vec{r}) \left[\int_{-\infty}^{+\infty} W_{tt'}(\nu,\vec{r}) \Sigma(\nu,\vec{r}) d\nu \right] d^3 r$$

- Σ=ISR spectrum (parameters N_e, T_i, T_r, v_0 ... not shown)
- ν=frequency
- W=spectral ambiguity function (the Fourier transform of the 2-D pulse ambiguity function)
- P=single scattering power
- R=radar coefficient, with calibration

- Calculated by experiment initialization
- Stored with experiment definitions

Outline

Requirements

- Matlab
  - **Matlab 2018a** must be patched with the most recent upgrade
  - Other releases should be fine
- Unix environment preferred
- Windows needs *bzip2* decompression utility
  - Option 1: run in **cygwin**
  - Option 2: install **7-Zip**

Get the distribution

Download

- Download `https://www.eiscat.se/scientist/user-documentation/guisdap-9-0/`
- Unpack the tar archive where you want it

OS-specific configuration

- Unix: make a link to .../bin/guisdap (e.g. in /usr/local/bin)
- Windows:
  - Edit windows_start.m
  - Edit anal/canon.m and make sure the path to 7-Zip is correct

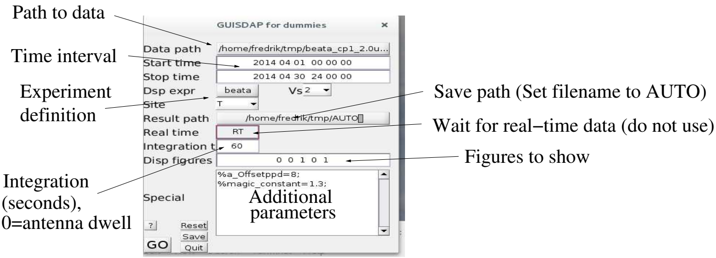
Starting GUISDAP

- Unix: type "guisdap" in a console.
- Windows: Make sure windows_start.m has been edited. **Right-click** on this file and select Run.

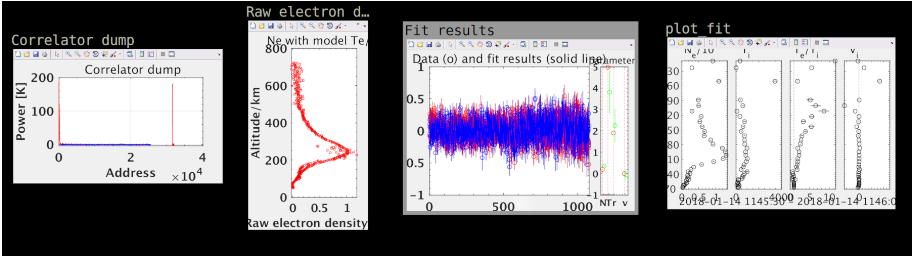
Matlab will start with paths set up.

- Type "analyse" (NB "s" spelling).
- This window will appear
- Click and main window appears

GUISDAP settings



Set and click GO



Note: plot fit parameters only for short tests, it is slow

Outline

Need for calibration?

GUISDAP corrects for

- Measured transmitter power
- Geometry
  - Antenna gain
  - Range
- Receiver chain response
  - noise source with known power

But. . .

Difference between calculated and actual antenna gain may be caused by snow or water in the antenna, etc.

Absolute calibration — Compare electron density

1. Electron density maximum and ionosonde foF2
2. Plasma lines

Calibration with ionosonde

- Find measured F (or E) layer peak N_e
- Get ionosonde critical frequency f_oF2 (f_oE)
- Calculate "true" N_e using the relation

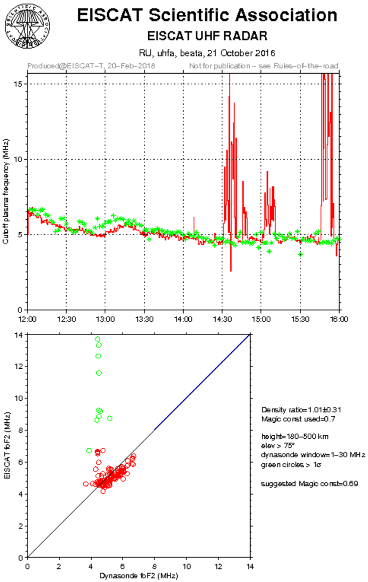
$$f_\mathrm{crit} = f_\mathrm{p} = \frac{\omega_\mathrm{p}}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{N_\mathrm{e} e^2}{\varepsilon_0 m_\mathrm{e}}} \tag{1}$$

Available in Tromsø. Svalbard ionosonde has been discontinued, unfortunately

Calibration routine

- You can do ionosonde calibration by hand...
- However an automatic routine exists: *calib_ne.m*

Calibration routine



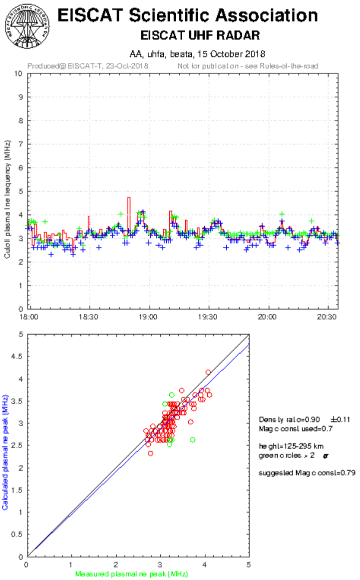
Plasma line calibration

- A direct measure of N_e
- Not always detectable by EISCAT
- Only available in certain pulse code experiments, see experiment document

In practice

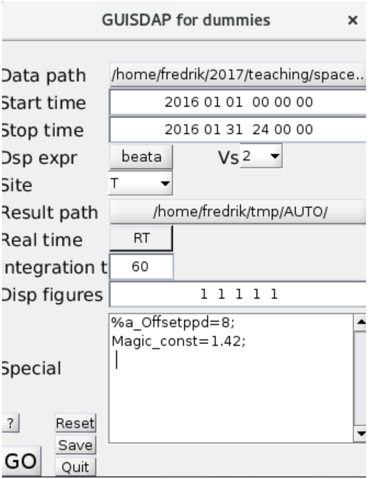
- Integrate plasma line data with GUISDAP
  - ESR folke Separate receiver, data in @32p directories
- Run *calib_pl_ne.m*
- Modify parameters in order to avoid misidentifying interference as plasma line peak

Plasma line calibration



Reanalysis with calibration

- Uncomment and set the "Magic_const" to
- This will scale the measured transmitter power



After this, we have results in physical units

Outline

GUISDAP output

AUTO directory naming structure

Directory name consists of: date, pulse code, integration time @antenna

Contents

- Matlab files
- Name is also time in seconds

Content of GUISDAP output

Experiment metadata

name_ variables e.g.

- site name
- experiment name

Results and instrument parameters

r_ variables

Content of GUISDAP output

Important result (r_) variables 1

- Time
- Azimuth
- Elevation
- Magic constant
- Tx power
- gfd structure (GUISDAP config)

Content of GUISDAP output

Important result (r_) variables 2

r_pprange	Ranges of raw power
r_pp	Raw power
r_ppw	Resolution

Content of GUISDAP output

The actual analysis results

r_range Ranges (weighted)

r_h Heights

r_param **Fitted parameters**

- Fitting is user definable e.g. ranges of fitting vs taken from models, limits
- Usually 6 of the 8 columns are used

Content of GUISDAP output

Contents of r_param

1. Electron density N_e [m^{-3}]
2. Ion temperature T_i [K]
3. Ratio between electron and ion temperature
4. Ion to neutral collision frequency [Hz] (default: taken from atmospheric models, not fitted)
5. Ion drift velocity v_i (the component along the line of sight, positive toward the radar) [m/s]. Note: By convention positive is away from the radar, so Vizu plot changes the sign of this parameter.
6. Composition $c = [\mathrm{O}^+]/N_\mathrm{e}$ [%], under the assumption that the ions are composed to c % of $[\mathrm{O}^+]$ and to $(100 - c)$ % of an imaginary ion with a mass of 30.5 u, that is, a typical value for a mixture of NO^+ and O_2^+ (default: constant at each altitude, not fitted)

Content of GUISDAP output

Error estimates

r_error Errors of fitted parameters

r_pperr Errors of power profile

Fit status

Content of GUISDAP output

Results are also converted to Madrigal format and uploaded regularly (manual operation)

Questions?

https://www.eiscat.se

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